# CASA Users Committee Annual Report 2018

**Committee members:**

Adam Avison (EU)

Ilse van Bemmel (EU)

Michael Bietenholz (NA)

Chris DePree (NA, Chair)

Yi-Jehng Kuan (TW)

Cornelia Lang (NA, not in attendance)

Se-Heon Oh (EA, not in attendance)

D.J. Pisano (NA, Deputy Chair)

Shigehisa Takakuwa (EA, not in attendance)

**Date of Issue:** 31 December 2018 (est.)

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# 2 Acronyms, Applicable and Reference Documents

## 2.1 Acronyms

| | |
|---|---|
| AAS | American Astronomical Society |
| ACDC | ASIAA CASA Development Center |
| ADMIT | ALMA Data Mining toolkIT |
| ALMA | Atacama Large Millimeter/submillimeter Array |
| ARC | ALMA Regional Center |
| ARDG | Algorithm Research & Development Group |
| ARTIST | Adaptable Radiative Transfer Innovations for Submillimeter Telescopes |
| CARTA | Cube Analysis and Rendering Tool for Astronomy |
| CASA | Common Astronomy Software Applications |
| CL | Chile |
| CUC | CASA Users Committee |
| HPC | High Performance Computing |
| EA | Eastern Asia |
| EU | European Union |
| EVLA | Extended Very Large Array |
| EWASS | European Week of Astronomy and Space Science |
| IF | Interferometer |
| NA | North America |
| NRAO | National Radio Astronomy Observatory |
| RFI | Radio Frequency Interference |
| TBD | To be determined |
| TW | Taiwan |
| SD | Single Dish |
| SKA | Square Kilometre Array |
| SRDP | Science Ready Data Products |
| VLA | Karl G Janksy Very Large Array |
| VLASS | VLA Sky Survey |
| VLBA | Very Long Baseline Array |
| VLBI | Very Long Baseline Interferometry |
| XCLASS | eXtended CASA Line Analysis Software Suite |

## 2.2 Applicable Documents

[AD1] CUC Charge (2014-09-16)
[AD2] Revised CUC Charge (2016-08-01)

## 2.3 Reference Documents

[RD1] CASA Users Committee - Terms of Reference
[RD2] CASA Users Committee 2014 Report
[RD3] CASA Response to the 2014 CASA Users Committee Report
[RD4] CASA Newsletter, issue 1
[RD5] CASA Newsletter, issue 2
[RD6] CASA Users Committee 2015 Report
[RD7] CASA Response to the 2015 CUC Report
[RD8] CASA Newsletter, issue 3
[RD9] CASA Newsletter, issue 4
[RD10] CASA Users Committee 2016 Report
[RD11] CASA Response to the 2016 CUC Report
[RD10] CASA Users Committee 2017 Report
[RD11] CASA Response to the 2017 CUC Report

# 3 Introduction

The CUC was formed in 2014 on the initiative of the National Radio Astronomy Observatory (NRAO) Data Management and Software Department. Its charge is to provide feedback from the CASA users community on capabilities, usability, reliability and performance of the CASA software package, advising the CASA development team in the user perspective on these matters and informing development priorities [RD1]. In 2016 this charge was revised to include year to year tracking of CUC recommendations [AD2, see 3.1].

The fifth CUC face to face meeting was held at NRAO Socorro on October 25-26, 2018. The goal of this meeting was to update the CUC on CASA developments, review actions taken in response to the 2017 CUC recommendations and provide updated recommendations for the 2018-19 cycle.

The attending CUC members were:
Adam Avison (EU)
Ilse van Bemmel (EU)
Michael Bietenholz (NA)
Chris DePree (NA, Chair)
Yi-Jehng Kuan (TW)
D.J. Pisano (NA, Deputy Chair)
*Aran Lyo (EA, attending for Se-Heon Oh & Shigehisa Takakuwa)*

Members who were unable to attend:
Cornelia Lang (NA)
Se-Heon Oh (EA)
Shigehisa Takakuwa (EA)
Chilean representative (not appointed)

At the start of the meeting, the CUC nominated and elected D. J. Pisano as its Deputy Chair. He will assist the Chair in the next months and eventually become the next CUC Chair in 2019.

## 3.1 Revised Charge [see also AD2]

1. Please comment on the capabilities, usability, reliability, and performance of CASA for current users of ALMA and the VLA. Should any of these areas be getting a significantly

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different allocation of effort than is currently the case? What areas would you de-emphasize as a consequence?

2. The committee should comment on CASA project follow-up to their previous report – whether it is sufficient, whether any activities should be emphasized or de-emphasized.

3. Committee organization:
    ● The CUC should appoint deputy chair who will become the next chair.

    ● As this is the fourth meeting of the CUC, rotation off of long standing members should continue as agreed upon during the 2016 CUC meeting *[Note: this revised charge was added last year. 2018 was in fact the fifth meeting of the CUC, and long standing members did rotate off last year.]*

# 4 Meeting Agenda

**Thursday, October 25, 2018**

| | | |
|---|---|---|
| 08:30 | Executive Session | |
| 09:00 | Welcome & logistics | Glendenning |
| 09:15 | CASA Overview and Statistics | Raba |
| 09:30 | Survey Results and Helpdesk Statistics | Emonts |
| | | |
| 10:00 | Break | |
| | | |
| 10:15 | Performance Overview | Raba |
| 10:30 | Performance - Static Benchmarks | Montesino/Castro |
| 11:30 | Performance - Dynamic Collection | Suoranta |
| | | |
| 12:00 | Lunch | |
| | | |
| 13:00 | CASA 6 | Schiebel |
| 14:00 | Pipeline and SRDP | Sugimoto/Tobin |
| | | |
| 15:00 | Break | |
| | | |
| 15:15 | Documentation Strategy | Raba |
| 16:00 | CASA Support for Polarization | Moellenbrock |
| 16:45 | CASA Support for VLBI | Moellenbrock |
| 17:00 | Executive Session | |
| | | |
| 18:30 | Dinner - El Sombrero | |

**Friday, October 26, 2018**

| | | |
|---|---|---|
| 08:30 | CARTA status update | Raba |
| 09:00 | CARTA features and demo | Wang |
| | | |
| 10:00 | Break - Move to Room 317 | |
| | | |
| 10:15 | Algorithm Research and Development | Bhatnagar |
| 11:00 | Discussion (in 317) | |
| 12:00 | Lunch (in 317) | |

13:30   Executive Session (in 317)

15:30   Preliminary report-out (open) (back in Auditorium)

# 5 Summary

The CUC is charged with commenting annually on the capabilities, usability, reliability, and performance of CASA for current users of ALMA and the VLA. In particular, we are charged with recommending whether any of the areas of focus for the CASA team described at the meeting should be getting a significantly different allocation of effort than is currently the case, and which areas should be de-emphasized as a consequence. This charge makes it clear, as the CUC understands, that NRAO has finite resources to allocate to the CASA effort, and that choices have to be made. Overall, the CUC feels that the CASA team is making wise choices for the allocation of limited resources.

The CUC had an informative two day meeting, and was overall very impressed with the progress that the CASA team has made in the past year. Ryan Raba (CASA Lead) had just started in his position last year, and it is clear that his leadership has shaped the efforts of the CASA team in important ways in the past year. Presenters across a number of areas addressed questions from last year's team regarding CASA capabilities and performance. Perhaps most importantly, the future direction of CASA was thoroughly described and set to a timeline, with an emphasis on modularity and usability of the software.

One major (and admittedly surprising) development was an impressive prerelease demonstration of the CARTA software. Several member of the the CUC were able to load large datasets quickly into CARTA, and easily manipulate datasets. Rapid deployment of CARTA as a highly capable replacement to the CASA Viewer should be a high priority, as the architecture of CARTA (separating the front end - view and analysis tools, and the backend - data storage) are instrumental to both the development of CASA and the SRDP effort.

Both the CUC and the CASA team should work to improve their regular communication between annual meetings each fall. As is discussed in the full report, we suggest a Spring teleconference at least between the CUC Chair, Deputy Chair and the CASA Liaison (Bjorn Emonts). Such an online meeting could help the CASA Liaison to achieve the goals of his position, namely to "help optimize and promote CASA for general use, as well as to push the capabilities of radio observatories (VLA and ALMA)".

The information gathered from the CASA User survey and the data collected from the new telemetry features in 5.4.0 onwards appear to be collecting valuable data which will help drive the direction of development in CASA into the future. Telemetry in particular will be of great

help in diagnosing issues with the software and the CUC were pleased to see the work being put into utilising these data.

The CUC appreciates the effort that the CASA team invests in this annual face-to-face meeting. As we did last year, the CUC would like to laud the excellent project management at all levels, ensuring progress and continuity of the project.

# 6 Focus Areas

Here we will summarize last year's recommendations, what the CUC learned this year, and make new recommendations for the coming year.

## 6.1 User Servicing

*2017 Endorsements/Recommendations:*
1. *Roll-out of a continued open and regularly monitored CASA users survey ( in format and content equivalent to our last year's recommendations) should be Imminent.*
2. *A first digest of the data collected should be presented to the CUC in spring 2018.*
3. *We encourage to continue recording and reporting statistics on helpdesk and JIRA tickets as well as user experience with the various Helpdesks for CASA users. Particularly, regional trends as well as the flow of ticket-based requests through the development process should be captured.*
4. *We repeat our request for a more detailed ticket summary, particularly if a ticket endorsement engine remains too challenging to implement.*

**2018 Endorsements/Recommendations:**
1. **We encourage NRAO to see if data on CASA issues as reported in the User Survey correlates with telemetry data that will become available in the coming year.**
2. **CUC Chair and Bjorn should schedule an early Spring 2019 meeting to discuss developments in the User Survey and other User related issues.**
3. **Some committee members seemed to feel that some issues were handled via email, and thus outside the Helpdesk. We hope that NRAO could determine the best way to send most if not all requests through the Helpdesk.**
4. **The User Survey should continue, and efforts should be made to maintain and increase the number of responses.**

Helpdesk response times seem to have improved in the last year or two, and the CUC commends this development, and the team fielding CASA Helpdesk tickets should continue getting the support and resources that they have been.

Many users, including members of the CUC, are sometimes reluctant to submit tickets because of the overhead compared to just sending a quick email. We recognize that NRAO needs the trackability of the tickets but it would be good to have an additional, less formal, channel of

communication. One suggestion might be to have an NRAO email address, or perhaps set up some sort of forum, that users can write to with questions about CASA and exchange information. Actual issues and/or bugs when identified here would have still have to get escalated to a ticket.

This year, there seems to have been a much better response to the User survey (>100), and the results of the survey in terms of User priorities mirror other sources of User data. This also seems to be a positive change from last year. It is important to continue regular User Surveys over many years.

Unfortunately, the mid-year communication between the Committee and NRAO did not happen. The CUC is committed to working with NRAO to have a Spring communication between NRAO and the Committee Chair and Deputy, if not the whole committee.

The Helpdesk data report was thorough, though we did not get information about the EU and EA Helpdesks, and that information would still be helpful.


## 6.2 User Outreach

*2017 Endorsements/Recommendations:*

1. *Promote recent improvements on reliability and performance at international workshops and conferences, and have a dedicated website for this which is continuously kept up-to-date.*
2. *We encourage a return to the twice-a-year Newsletter cycle and to keep monitoring the readership data.*
3. *Consider deprecating the moribund CASA forum and instead start a dedicated CASA facebook group.*
4. *Seek to reveal prominent issues users are facing by identifying different helpdesk tickets of similar content and, possibly, regional trends*
5. *Improve visibility of CASA at large astronomy meetings*

*2018 Endorsements/Recommendations:*
1. **The user survey was very successful and provided very good insights. We recommend to keep it running. The question about 'reliability' should be handled with care.**
2. **The Newsletter is currently the main channel of communication to users, and well maintained. For accessibility the layout and format could be optimized.**
3. **We would welcome an update on the Newsletter readership statistics.**

4. *There is room for additional communication channels besides the Helpdesk and Newsletter. We encourage NRAO to investigate the needs from both developers and users to exchange information, and identify solutions.*
5. *We suggest to have a set of CASA outreach materials (slides, posters, flyers) to promote CASA at meetings.*

Over recent years the reliability of CASA has continually improved, but the community's understanding of this seems to be lagging behind. Feeding information to the astronomical community at large is an important undertaking and something we encourage the CASA team/liaison to continue to do. This can and has been achieved both through the Newsletter and CASA website and, to reach those not yet using CASA, by advertising the software and its recent developments at large astronomical meetings.

The CUC are pleased to see the return of a regular CASA Newsletter, one of last year's recommendations. Concerns expressed by the CASA team and liaison about readership levels/time spent reading the Newsletter would suggest a fuller investigation of the users' experience with the Newsletter be conducted. A related recommendation from this year (6.2.2) is to investigate formatting the Newsletter layout so as to not present readers with an overly large amount of information on initial inspection, this may help with perceived low interaction levels. Annual updates to the CUC on Newsletter statistics are encouraged (6.2.3). An additional channel for communication along side the Newsletter would be the use of social media, a technique successfully used by other institutes and software teams (6.2.4).

The CUC notes that the Newsletter is the main channel communication from the CASA development team to the users, but a channel for communication in the other direction (aside from filing a Helpdesk ticket) is not clear, a continuing concern from last year's recommendations. The revitalisation of the CASA forum, or some similar framework, is one available option and would broaden the pool of `experts' beyond the CASA development team to a more peer-to-peer support system. We encourage the NRAO/ the CASA liaison to investigate potential avenues for this that best fit within NRAO's structures.

To expand the CASA user base and knowledge of recent developments in the software to the broader astronomical community, participation at appropriate large international meetings (e.g. AAS, EWASS) is valuable. The CUC acknowledges that logistically it can be difficult to have an NRAO representative at all appropriate meetings and suggest that the CASA team develop a set of CASA outreach materials (slides, posters, flyers) to promote CASA at meetings (6.2.5) to be

presented by volunteer "CASA superusers", e.g. members of the CUC, ARCs (and Nodes), JIVE, who may be easily able to attend regional meetings.

The information gathered from (1) the CASA User survey, and (2) the new telemetry features in 5.4.0 onwards are providing valuable data which will help drive the direction of development in CASA into the future. Telemetry in particular will be of great help in diagnosing issues with the software and the CUC were pleased to see the work being put into utilising these data. The CUC do suggest that the use of telemetry data be initially used for the primary purpose of baselining/normalising task usage against crash reports before exploring any additional uses (e.g. specialized user support, as was discussed during the face-to-face meeting).

## 6.3 Documentation

*2017 Endorsements/Recommendations:*
1. *All stakeholders (incl. The CUC) should continuously promote the achievement of the new plone documentation system and make sure that the users get used to the new system.*
2. *We recommend to investigate solutions to have outdated Google links being curated.*
3. *We endorse the aggressive timeline for finishing up the inline help and encourage to continue cleaning up the CASA webpage for improved usability. Clean-up of the CASAguides page may also be advised.*
4. *Monitor and digest CASA-related helpdesk tickets, and verify how well the new documentation system (CASA docs, CASA guide, etc) helps the users.*

***2018 Endorsements/Recommendations:***
1. ***We applaud the efforts to fully populate the online CASAdocs, and would like to see it extended to the rest of CASA***
2. ***We would like to see recommendations on the usage of tasks (e.g. tclean vs. clean) and capabilities (e.g. parallelization)***
3. ***We recommend the inclusion of verification tests and more detailed explanations of tasks both for experienced users and to improve perceptions.***

The committee appreciated the new documentation available for some of the CASA tasks, and looks forward to this work being completed for the remainder of the tasks. There do not appear to be plans for extending this level of documentation to other CASA functionality to assist astronomers who have to work with CASA tools. For example, there is a lack of documentation on accessing the CASA logger, and recent changes to the logger were not documented either.

The lack of documentation both affects usability and perceptions of CASA, particularly for newer users and those who are trying to reduce their data outside of pipelines.

The committee encourages the CASA team to make some of the existing, internal documentation available to the community as well. This would include modification requests, specifications for changes to or new functionality, and results from verification tests. This would help build confidence amongst users that CASA is, indeed, working as advertised. This is particularly relevant for new capabilities, such as the parallelization of CASA.

While we understand preserving old functionality (such as *clean*) as new functionality is being developed (such as *tclean*), the current CASA documentation does not make it clear enough which task should be used. This is particularly a problem when naming conventions are not as consistent. So *tclean* is the new version of *clean* (the latter being deprecated), while *split* is the new version of *oldsplit* (which will be deprecated). Ensuring that the tutorials, release notes, and change logs make it clear which task should be used is essential. Furthermore, we would recommend a consistent naming convention for tasks such that it is more obvious what should be used and what is being tested or has been deprecated.

Finally, the committee agreed that all of this documentation should be available offline, either in CASA or through webpages/PDFs distributed with CASA. While offline documentation is harder to keep up to date (and could be updated perhaps less frequently than online support documents), it would allow users to work with CASA when they lack good internet connections. This offline capability is particularly important if CASA is going to become the standard for radio data reduction and analysis around the world.

## 6.4 Performance, Computing and Reliability

*2017 Performance Recommendations:*

1. *Work out concise and transparent performance benchmarking metrics and provide these resulting benchmarks in a visible manner.*
2. *Implementation of a runtime predictor, at least for selected tasks, is a desirable feature of an upcoming version of CASA.*
3. *Continue to make progress in development of plone documentation for parallel-mode CASA and strongly encourage the respective communities to publish a specific casaguide on parallel computing.*
4. *Keep pressing on cloud computing solutions and explore more ways to engage users in this effort. Also be more active in promoting the new cloud-based resources towards interested user communities.*

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*2017 Reliability Recommendations:*

1. *The committee is pleased with the implementation of the crash reporter and initial results. NRAO should seek to improve on the quality of data collected by the crash reporter (e.g. noting "in house" versus "in the wild crashes).*
2. *As stated last year, the committee sees a possible gap between the implementation and the quality of data collected. We encourage the definition of simple but concise metrics and keeping track of user IDs for a clearer first picture of the significance of particular failures.*
3. *The importance of a successful user survey cannot be overstated. The survey data should be used to determine the needed levels of support for various platforms, and user perceptions about the stability and reliability of CASA.*

**2018 Recommendations:**

1. **The Crash Reporter and telemetry included in CASA 5.4 are excellent tools to obtain feedback on CASA performance and reliability. Since there is a wealth of applications for this data, we recommend to focus the efforts on some well defined goals.**
2. **The performance of CARTA was very impressive, and the plan to make this a client-server application will help to keep this light-weight.**
3. **There is a split in the CASA user base between pipelines and single users. Different performance metrics are needed for pipelines and single users, and long term strategies need to cater to both user bases.**
4. **The performance metrics shown at the meeting are impressive. The committee recommends making these metrics available to users, as they can be especially helpful for pipeline development and maintenance.**
5. **If possible, the development of a CASAmark (analogous to the olds AIPSmark) would be helpful to determine the necessary computing power for typical CASA use cases.**

With the majority of CASA users utilizing pipelines, it makes sense that the development choices are aimed at improving their performance and results. However, unique and high impact science, as well as pipeline development, will come from single users who will push the software to its limits (or beyond) to do new things. These users need to be considered as well. In terms of performance and reliability, this implies that it would be helpful to identify the origin of Crash Reporter and telemetry statistics, and to ensure that both user bases are being served. The telemetry data in particular opens up a wealth of possibilities, and the committee recommends to carefully identify what the main purpose(s) of these data will be.

With the ongoing work, last year's recommendation related to run-time indicator has been superseded by the implementation of telemetry. There seems very limited interest in cloud based solutions, and with increasing parallelization in CASA there is no direct need for this. Also, the CUC was impressed with the ongoing work to improve the online documentation, and the new design/layout is a major step forward.

The perceived image of CASA as slow and unreliable is changing, but this perception still needs active engagement on the part of NRAO. Again, it is also important to acknowledge that there are two separate user audiences with distinctly different needs. Pipeline developers have already made a choice for CASA, and will mostly require help in optimizing their processing. The performance analysis shown at the meeting is a very useful collection of metrics, and the committee recommends to make these metrics available for pipeline developers.

Single users will use the CASA package in a more interactive way, and in some cases still need to be convinced to use CASA instead of other data reduction and analysis packages. The performance metrics for this audience could include an equivalent of AIPSmarks (a test to see if a particular computer is suitable for CASA processing). Direct comparisons with other existing packages could help to generate more objective opinion of CASA performance and reliability.

# 6.5 CARTA

*2017 Endorsements/Recommendations:*
1. *We strongly advise to follow the currently planned roadmap, i.e. rolling out CARTA as part of the 2018 fall release of CASA.*
2. *We recognize the challenges to have the full envisioned feature-set (comparable to the CASA Viewer functionality) implemented and recommend to expand on the features within one year after the initial release.*
3. *We strongly encourage to closely monitor the project's progress/interim goals and suggest continued maintenance of the CASA Viewer as a fallback option.*
4. *We repeat our last year's recommendation to keep CASA users informed about the imminent transition from the Viewer to CARTA.*

**2018 Endorsements/Recommendations:**
1. **The demonstrated v0.9 of CARTA was impressive in its capabilities**
2. **The CUC would like to have a list of the features that will be in the December release, and a more complete timeline of feature implementation in order to more fully comment in our report**

3. ***Could the v1.0 release be demonstrated at the January 2019 AAS meeting (at the NRAO area of the convention hall)?***

NRAO and its collaborators have made huge progress on this front since last year. The CUC applauds the efforts to get CARTA running as a viable CASA Viewer replacement. The changes in the management of the CARTA effort seem to have had a positive effect, and the CUC encourages rapid development of CARTA as a permanent CASA viewer replacement in an upcoming distribution of CASA.

It would be helpful to the user community to have a more complete timeline of CARTA feature implementation in upcoming releases. The CUC discussed whether NRAO would be able to demonstrate the current capabilities of CARTA at the January 2019 AAS meeting in Seattle.

Several members of the CUC were easily able to download and use the beta version of the CARTA software shared at the meeting, and were impressed with the performance speed, even with large datasets loaded onto a modest laptop.

## 6.6 Pipelines & SRDP

*2017 Endorsements/Recommendations:*

1. *We agree that resolving remaining issues of parallel computing in the imaging pipeline should be a top priority and recommend the pipeline team to provide users with a reliable and stable product.*
2. *We recommend to assure smooth transition in the pipeline development lead position in order to continue the good work seamlessly.*
3. *We encourage further development of the planned NRAO Archive interface with imaging pipeline integration and suggest to keep other stakeholders (the ALMA Archive in particular) closely informed on the solutions developed.*

*2018 Endorsements/Recommendations:*
1. ***The relationship between SRDP and CASA needs to be better defined in a long run.***
2. ***The progress of the pipeline team besides parallelization is impressive and the excellent performance of the team in the past is continued under the new leadership.***
3. ***Improvement toward less intervention in both interofermetric and single-dish cases is anticipated in the near future.***
4. ***Priorities for ALMA Cycle 7 Pipeline are properly set overall, especially in reducing human intervention in QA time. However, higher priority should be given to handling***

*of strong telluric absorption lines in calibration for ALMA, as it's critical in the submillimeter regime for ALMA spectral observations.*

5. *It would be instructive to provide some brief introduction and/or explanation of the pipeline scripts executed together with the data delivered.*

6. *The pipeline webpage should be made more known and public to general CASA users.*

The CUC was impressed by the significant progress made by the pipeline team with the new lead. Besides reducing human intervention in QA, the CUC recommends that the pipeline team dedicate effort to telluric line removal in order to secure proper calibration of ALMA spectral data, which suffer most from strong terrestrial interference.

It would be both helpful and more user-friendly to novice users to have a brief introduction and explanation of the applied pipeline script bundled together with the delivered data without going through extra steps of CASA web searching. Currently, the ALMA Imaging Pipeline Reprocessing webpage is little known to general CASA users except ARC members. It would be nice if CASA team can make the pipeline webpage obvious at the CASA homepage, or highlight it for users in the coming year through established channels (e.g. AAS meetings, CASA Newsletter).

The CUC appreciates being informed about the SRDP timeline. Although CASA pipelines are considered to be the foundation of SRDP, more clarity in communicating to the user community the relationship between SRDP and CASA would be helpful, given their different missions.

Somewhat more detailed documentation on the requirements and workings of the ALMA and VLA pipelines would be useful in CASAdocs. For the VLA pipeline, for example, perhaps the documentation could include including explicit recommendations for (likely) frequent-use cases such as running the pipeline on a Measurement Set which is only part of a SB, or has been averaged in time of frequency to reduce data-size.

## 6.7 Imaging Developments

*2017 Endorsements/Recommendations:*

1. *We encourage close interaction of the CASA team and the novel NRAO Algorithm Research & Development Group (ARDG) in order to make sure that imaging-related developments are well synchronised and adjusted to the user needs*

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2. *We encourage both the ARDG and CASA team to keep track of external development efforts in the area of usable and reliable tools for single dish/total power combination with interferometric imaging.*

***2018 Endorsements/Recommendations:***
1. ***We encourage the ARDG to advertise their work at conferences/summer schools as this would be beneficial for both increasing the CASA user base and increasing collaboration on algorithm development.***
2. ***A tutorial of how to base algorithmic developments on CASA (e.g. via a Jupyter notebook on the CASA guides webpage) using the new modularized CASA 6.0 would be valuable and help encourage international effort.***

The CUC were pleased to see the developments being made by the ARDG in the fields of single dish+interferometer combination, wide-field imaging and MPI imaging. The reported works look very promising and the algorithms/techniques being pursued are timely for the current and upcoming capabilities of modern/future interferometers which will utilise CASA. We encourage ongoing collaborative efforts of the ARDG and CASA development team in each of these fields and recommend the use of the CASA user survey to help guide the direction of future research lead algorithm developments, while recognizing that the ARDG is a research-intensive group and not entirely driven by the needs of the CASA user base.

With regard to the 2017 CUC report recommendations, progress is being made of both counts. From the involvement of ARDG members throughout the CUC face-to-face meeting there appears to be an appropriate level of interaction between the CASA development team and the ARDG. The CUC encourages interaction particularly in cases where ARDG work relates directly to the current demands of the CASA user base.

The CUC has noted over the previous two years reports that the community is in need of a robust tool for single dish + interferometer combination and imaging and to keep track of external developments. As such the results presented by the ARDG and the associated delivery time of Q3 2019 are timely, though the relation to external (non-NRAO) work is less clear. We encourage the fulfilment of the ARDG's proposed delivery time to allow the inclusion of the ARDG joint imaging technique into a CASA release (and related documentation/casaguides) as soon as possible within the CASA release cycle. The CASA team or relevant stakeholders may wish to advertise the Rau & Naik ApJ paper (submitted) via the CASA Newsletter when published.

## 6.8 Interaction with the CUC

*2017 Endorsements/Recommendations:*
1. *The CUC hopes to stay informed about the future deliberations of the stakeholders committee and again encourages to have Bjorn Emonts as liaison person taking part in the committee meetings.*
2. *As last year, we request a report/update from the stakeholders committee next year.*

***2018 Endorsements/Recommendations:***
1. ***Having access to an agenda or list of topics discussed by Internal Stakeholders would help keep the CUC informed during the year so that we can be better informed at the fall CUC meeting.***
2. ***The CUC recommends improving communication between the committee and the CASA User Liaison in between the CUC meetings.***

The annual CUC meetings provide a lot of information on the state of CASA in a relatively short period of time. However, a substantial amount of work and decisions regarding CASA are made over the course of a year. The CUC would find it useful to receive regular updates throughout the year on the state of CASA work and the topics being discussed by the internal stakeholders (see section 6.1 above). This recommendation is not so that the CUC can approve or reject decisions made during the year, but so that we are more familiar with progress and issues that arise before the annual meeting begins and can more effectively use the time during our meetings to provide valuable feedback. Of course, if feedback is desired at other times in specific situations, the CUC is willing and able to respond to those requests.

## 6.9 External Contributions

*2017 Endorsements/Recommendations:*
1. *Indicate those changes in new CASA releases that change interfaces and summarize these in the release notes.*
2. *Seek to improve the communication with external developer teams, particularly the interaction between the CASA software validation management and larger external Projects.*
3. *Publish a guide to the build process.*

*2018 Endorsements/Recommendations:*
1. *With the VLBA coming back into NRAO, and the ongoing development of SRDP, the committee recommends investing in making CASA fully VLBI-capable and securing resources to maintain this capability for the longer term.*
2. *Collaboration with third parties is an excellent way to implement functionality for very specific applications in CASA. The process to include new functionality is somewhat obscure, and the committee recommends a closer feedback loop with external parties to ensure their continued commitment, and successful delivery of CASA products.*

As mentioned above, unique and high impact science results are typically expected when users push existing methods and software to their absolute limits and beyond. This frequently involves small but significant changes to the software, and an excellent example is the use of CASA as one of the three equivalent pipelines in the first science release of the Event Horizon Telescope. The Confluence JIRA system is an excellent way to maintain ties with external developers. In addition we recommend that NRAO (where possible) set up a tighter communication with external teams to discuss planning and changes to release schedules, so everyone can plan the work in the most efficient way. In this sense, Recommendation 6.9.2 is a merging of previous recommendations. Since the most recent meeting of the CUC, active involvement from NRAO has improved for VLBI implementations. A similar model with an NRAO point of contact is recommended for other external contributors.

The committee is impressed with the inclusion of new VLBI specific tasks and functionality, and the growing interest in the VLBI community to move to CASA for data processing. On the longer term there is interest also from the Square Kilometre Array (SKA), which is in essence also a VLBI-type instrument. We recommend that NRAO look carefully at how to position CASA, or parts of the CASA framework, as a potential data processing package for SKA and SKA-VLBI, and actively develop capacity to join SKA in global VLBI networks. For the near future the change to Python 3 should be advertised to all external developers well in time. The eventual development of MS 3 is a positive development along these lines.

The CUC also took note of the new developments in polarization calibration in CASA. There is clearly need for this in the user community, but expertise within the committee on this topic is limited. We do encourage this development and would recommend that in the near future the CUC is joined by another member with expertise on this topic.

## 6.10 CASA Users Committee Membership and Organization

As always, the CUC was impressed with the level of effort and the quality of the work that the CASA team has undertaken in the past year. For the past few years, attendance and a complete slate of CUC members has been an issue. We assume that this is because many members have to travel great distances to come together for this meeting. Despite Brian Glendenning's best efforts, there is still not a Chilean representative (as we understand it), and a number of current committee members were unable to attend this year's meeting for various reasons. The workload for members increases significantly when there are fewer actively involved CUC members, and we urge NRAO to continue to identify Committee members who will be able to consistently attend this important annual meeting. We also hope that there might be any way for the NRAO Director to motivate Chile to contribute a member to this Committee.

For the coming year, we would like to request to have any new appointments/replacements to the CUC completed by April 2019. The CUC envisions holding a telecon by May 2019 during which turnover of members and Chair will take effect. Sharing the membership rotation schedule would be helpful to the CUC to identify if there are other future years in which a significant number of CUC members will rotate off the committee. The CUC emphasizes that overlapping expertise between CUC members recruited by NRAO is encouraged, especially for topics that are high on the NRAO-CASA agenda.